AQUARIUM MAINTENANCE MANUAL

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INTRODUCTION

The marine environment, in Hawaii, contains beautiful coral reefs and unique animals. Many who visit these waters, are desirous to bring a "little slice of the ocean" home with them in the guise of an aquarium.

Aquariums are fun to have and the animals a joy to watch in the confines of this "mini-ocean" set-up. This desire to set up and maintain an aquarium is often tempered with the thought that aquarium-keeping is a time-consuming and difficult task to undertake.

This manual is a brief primer to help the would-be aquarist follow a step-by-step process in the establishment and maintenance of either marine and/or freshwater aquariums. The information contained herein was garnered from fourteen months of aquarium-keeping by students of the Marine Option Program whose skill project was in Aquarium Management. Much was learned the "hard way" about aquariums through failures and successes.

Such knowledge is hereby presented for use by others who desire to join in the fun of keeping aquariums the successful and easy way! Within this manual, information can be found regarding necessary equipment, types of food, water quality, the nitrogen cycle, maintenance procedures and other helpful hints.

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OBJECTIVES

The primary objective of this project was to establish and maintain marine and freshwater aquariums for the University of Hawaii Marine Option Program. In doing so, knowledge would be accumulated on behavioral considerations, feeding requirements, and disease prevention, and this knowledge passed on to other interested students of aquaria. Additionally, the opportunity would be provided to MOP students to observe fish, to study their behavior in an enclosed environment, and to simply enjoy the beauty of the aquariums.

NARRATIVE

The project officially began April 1983 with the acceptance of the project proposal, and is now being completed, July 1984, with this final report.

The project began with two tanks, an 85-gallon saltwater tank and a 15-gallon freshwater tank. Both were established and in operation with a variety of animals. During the period of this project, five more tanks have been acquired; all are currently in operation.

Each tank was set up and maintained by the project members. This involved the initial preparation of the tanks, collection of water, the addition of animals, monitoring of water quality, feeding of the fish, and the daily entries in the aquarium journal. Once a month a water change and tank cleaning was made of each tank. A quarantine tank was usually set up and maintained for observation and care of new fish.

DATA

The data gathered and recorded in the daily journal was segregated by specific tanks. The notation was made on eating/not eating, type of food given, physical appearance of fish, interaction of species, and other pertinent data. Notation was also made, on a weekly basis, of the salinity and nitrite readings in the saltwater tanks.

SALINITY

Salinity measures the quantity of dissolved inorganic solids (salts) in the water, and is usually measured in parts-per-thousand, or ppt. Most tropical seas are 34 to 35 ppt (35 grams of salt in one kilogram of water). Freshwater with no dissolved salts, is measured at 0 grams/kilogram of water.

Salinity measurements were taken with a floating-type bulb hydrometer or a hand-held hydrometer. The hydrometer measures specific gravity. Specific gravity is a ratio or comparison of the weight (density of saltwater to the weight of an equal volume of pure water. Thus, since one (1) represents the value for pure water, a heavier substance such as saltwater will sink and has a specific gravity greater than 1. The specific gravity for tropical saltwater aquariums should be 1.025, with a range of 1.023 - 1.027.

Evaporation causes a constant increase in the total salinity since only pure water evaporates and the salts are left behind. When specific gravity exceeds that range, freshwater was added to bring the specific gravity within the correct level.

At certain times and with certain invertebrates, a lowered salinity may be recommended. Lowered salinities keep more oxygen in the water, allow the nitrifying bacteria to work more efficiently, and reduces the workload of the fish. This factor can be beneficial, especially to fish that are under stress or are ill. Reduced metabolic workloads allow the fish to put this energy elsewhere.

All fish, freshwater or marine, carry salt levels in their blood and cell tissues. Freshwater fish do metabolic work to prevent loss of salt to the surrounding fresh water, and marine fish work to prevent loss of freshwater from their bodies. They are always taking salt in through their mouths and excreting it through their gills. Water is always leaving marine fish while in freshwater fish water is always going in. This difference in salinity requirements of freshwater and saltwater fish is the reason mixing them in the same aquaria is not possible.

Water is removed from marine fish because salt density of tissue water is less than ambient water environment. If the salinity of the water is high, the metabolic workload of the fish is increased in trying to prevent excess loss of tissue water.

NITRITE

When an aquarium is first set up the most important problem arises from the buildup of nitrogen-containing materials in the water. These result from the activities of bacteria that change animal excretions, leftover food and dead material from one kind of chemical to another. The most toxic of these chemicals is ammonia, which appears early in the series of transformations that involve nitrogen. (See section on the NITROGEN CYCLE)

During the nitrogen cycle, ammonia is oxidized to nitrite and nitrite to nitrate, respectively. Ammonia and nitrite are toxic; the end product nitrate, is relatively non-toxic and can be allowed to accumulate in the aquarium without much concern.

Ammonia status in the aquarium need not be monitored since, within a few days, the appearance of nitrite will indicate that the ammonia has been converted to the less toxic nitrite. Nitrite is monitored by use of a nitrite test kit. The test indicates the presence of nitrite by producing a red-colored solution with intensity proportional to the amount of nitrite.

Nitrate, the end product, is transformed into nitrous oxide and free nitrogen, which are not as harmful to fish as is nitrite and ammonia. If the aquarium is allowed to develop pockets of low oxygen or anerobic conditions, bacterial reduction of nitrate can produce toxic compounds. Nitrate can also increase over time and accumulates in the system. Nitrate can most easily be removed by dilution through partial, periodic water changes.

Nitrite monitoring during the first six to eight weeks of a new aquarium is critical to the success of that aquarium. Periodic checks during the remaining period of the "mature" aquarium is to assure that no increase in nitrite is occurring. If an increase is noted, this usually indicates there is a large amount of organic matter (e.g., dead fish, excess food) decomposing, hidden under some coral or rock, or that sudden "die-off" of bacteria or algae is taking place.

Healthy reef fish will survive at the level of nitrite in the vicinity of eight to ten parts per million for a day or two. If the level does not drop within twenty-four hours, half of the water in the aquarium should be changed. This dilutes the nitrite to a safer level. Nitrite levels should not exceed one or two ppm in a healthy aquarium.

This nitrogen cycle operates the same in the aquarium as it does in the sea; however, the sea is a balanced system in which great volumes of water, in constant movement, and with other factors work together to maintain good water quality. It is a real challenge to the aquarist to obtain this same healthy balance in the nitrogen cycle.

ANIMALS IN THE AQUARIUMS

There was a wide variety of animals, both invertebrates and vertebrates that were kept during this project because of the multiple number of aquariums and the use of both salt and freshwater systems.

The animals were obtained in a variety of ways: captured by the Project Members or by other students, bought at the pet shop, or donated from students' home aquariums. Organisms were usually chosen for the aquariums with consideration given to species, size, aggressiveness, feeding requirements and behavior of the fish.

Behavioral considerations:

Some species of fish are more aggressive than others, and some of the same species will even kill one another unless removed from the same environment. In general, fish are more aggressive toward their own species than towards others. The fish of the damsel family (e.g., *Abudefduf sp.*) were most prone to this type of behavior, proving so in the aquariums. Some had to be removed and either returned to the sea or placed in another tank where they could be more suitable tankmates.

Fish with strong predatory characteristics (e.g., lionfish, groupers, eels) cannot be kept with small "bite-size" individuals unless they are fed well; a prevention to keep them from eating the smaller animals.

Much aggressiveness is related to space and territory. The providing of enough hiding places and areas in which to roam helped to reduce the aggressive behavior of some species. Larger animals generally needed a larger territory to "control" than the smaller animals. In mixing large and small fish, sufficient sites of concealment (e.g., coral heads, rocks) were provided for the small and less aggressive fish to take protective cover.

Feeding considerations:

Some fish are carnivores, some herbivores, and some omnivores. These latter types were the most frequent inhabitants of the aquariums because their diet requirements were most easily met. In the natural environment, fish are constantly roving about searching for and eating food. Some fish are bottom feeders, some are surface feeders, some are aggressive eaters, while others are much more timid in their approach to eating. Mixing these fish in the same aquarium can be a problem, as the aggressive fish seize all the food and the more timid ones starve. Trying to provide enough food for the timid fish to eat may cause water pollution due to uneaten portions of food decomposing in the tank. These fish, which do not compete well for food, must be removed to a tank with less aggressive inhabitants.

a) Freshwater fish: The freshwater fish would eat a variety of foods. The food type used the most was a flake food composed of animal protein, freshwater algae and cereals. Pellets, composed of the same basic ingredients was offered to the fish but were usually refused until the fish became extremely hungry. The removal of the uneatened pellets was required to avoid polluting the water. At times, live fish, (e.g., minnow) was offered to the African cichlid. Live food was readily accepted but not always available. Raw meat was offered (e.g., pieces of fish fillet) but was always rejected. The fish were fed twice daily with enough food they could consume within five minutes of feeding. If all was eatened more was offered.

The fish had a fondness for many of the green plants placed in the aquarium for decoration, particularly the plant Anarcharis sp.. Every month these plants would have to be replaced because the fish would strip each stalk of its tender leaves.

b) Freshwater newts: The newts were easy and interesting to care for. The diet that had been recommended for them was a commercially prepared pellet of protein and plant products. Few cases of eating was actually witnessed and it was assumed they ate them later in secret. Later, a diet of live brine shrimp was tested. This they seemed to enjoy with great relish, as they did the raw fish fillet offered to them. Raw fish fillet should not be offered everyday because it is too rich a diet. Other recommended food types are fruitfly larvae, live tubiflex worms, and baby crickets. The newts were fed each day during the afternoon and had become relaxed enough for us to hand-feed them.

c) Saltwater fish: The saltwater fish combined a variety of omnivores which were fed an assortment of foods: dried brine shrimp, frozen brine shrimp, live brine shrimp, flake food, and pieces of raw fish. They were offered this diet morning and afternoon, and were fed what was consumed within a five-minute period. If they still appeared hungry, additional food was offered them. The invertebrates were fed once a day.

The carnivorous fish, whether eating raw fillet or only live food, were some of the most interesting fish to keep. The animals that would eat only live food were, perhaps, the most difficult to keep since a supply of live feeder-fish was not always available for their feeding requirments. The feeder-fish were of freshwater types, such as guppies, minnows, and small talapia or cichlids. Caution is advised upon feeding carnivores pollywogs (tadpoles); these contain toxic substances and will result in the deaths of prized marine fish.

The animals that would eat any type of raw meat were usually invertebrates, though the vertebrates (omnivores) enjoyed being fed small amounts too. The invertebrates were fed raw shrimp, octopus, and white fish (sole, mahi, butterfish, halibut). Red fish was not offered because it contains a great deal of fat which could easily pollute tank water.

The invertebrates were offered food everyday, but some only ate every other day, while others went for weeks without eating. If they ate they were usually offered food until they no longer came to feed. Most of the invertebrates were fed by hand.

Quarantine Procedures:

The majority of vertebrates were placed in a quarantine tank for a period of three weeks prior to introduction to their display tanks. The quarantine tank water was medicated with antibiotics or with a copper sulfate solution. Fish treated this way prevent the introduction of pathogenic organisms into the larger display tank, rid the new fish of these organisms, and gave the new fish time to become acquainted to a confined environment and to adapt to new and strange foods as well as to people. After the quarantine period, the fish were introduced into their new home during the one to two hour period of acclimation. At the end of this period, they were allowed to swim freely into the tank.

Some fish were merely "dumped" into the display aquariums by MOP students without this quarantine procedure. The fish often did not survive, and at the same time brought harmful organisms into the larger tanks.

Invertebrates cannot be treated with medications. The only method that is usually recommended is to place the animals in a tank (without medication) for a period of a few weeks to observe its "survivability" and disease-free appearance. An experimental method was tried: certain specific animals were given a 60-second freshwater dip (in water of the same temperature). This would usually rid them of any parasites or other harmful organisms. Any external parasites, not deeply imbedded, quickly takes up water and burst from the increased osmotic pressure. This method has been used with some success on featherduster worms, anemones, crabs, sea cucumbers, sea stars, and sea urchins.

EQUIPMENT

All equipment used in marine tanks -- air tubes, airlifts, siphons, filters, etc. -- should be made of glass, plastic, or other specific synthetic materials in order to be as corrosion-proof as possible for the aquaria. Saltwater is far more corrosive than freshwater.

EQUIPMENT NEEDED TO SET UP

non-metallic tank
undergravel filter
filter medium
air pump and tubing and/or an external outside power filter
hood cover and light
decor
water
other useful equipment

BASIS FOR EQUIPMENT SELECTION

Non-Metallic Tank

The tank may be constructed of glass or acrylic. All the tanks in the MOP aquaria project were made of glass, therefore, acrylic tanks were not tested as to suitability. They are, of course, lighter in weight and cheaper in cost, as well as can be constructed in various shape configurations not usually available in glass tanks. The acrylic tank has the disadvantage of being scratched easily but this may be polished out.

Metallic, concrete, or wood tanks are not recommended because they are difficult to adapt to aquarium use unless coated with a plastic non-toxic resin, a very time-consuming and expensive process.

Size of Tank

The tank sizes used in the MOP aquaria project consisted of (1) 10-gallon, (2) 15-gallon, (2) 40-gallon, (1) 55-gallon, (1) 85-gallon, and (1) 100 gallon.

The smaller tanks were used for freshwater aquaria and one was used as a saltwater quarantine tank. The minimum saltwater size recommended for beginners is a 20-gallon tank. Smaller tanks tend to foul much more readily because they leave little margin for error for the physical and chemical changes that occur. In a larger volume of water these changes occur less rapidly, thus, there is greater leeway for error. Small tanks also tend to be overcrowded.

The sizes for freshwater aquaria is not as critical. Freshwater fish are less active and generally produce less waste materials to foul the water quality of their environment.

Another factor to consider in size selection is the weight of the filled tank. A gallon of seawater weighs nearly 8 1/2 pounds (8.34 pounds or 3800 grams, to be exact). Therefore, a 20-gallon tank, when filled with seawater, exclusive of substrate materials (gravel, rocks, sand, etc.), decorations, hood covers, lights, and other apparatus, weighs 170 pounds. A gallon of freshwater weighs slightly less. (The gallon capacity of the tank can be easily calculated by multiplying (in inches) the length times the width times the height of the tank and then dividing this number by 231.)

It is imperative that the support stand and the floor area under the stand be able to support the weight of the tank BEFORE it is placed in location and filled with water. This was of prime consideration in the location of the 100-gallon tank, located in the Marine Science Building -- second floor lobby. This tank, when full of water, 850 pounds of seawater, plus the weight of the other necessary adjuncts, would easily tip the scales at 1000 pounds. While it is true that weight spread out or distributed over a larger area will create less stress than will the same weight in a smaller area, the consideration of poundage of the aquarium must be of prime concern to the aquarist.

<u>Shape of Tank</u>

Shape affects the filtering capacity of the tank and, therefore, the filtering capacity and quality of the water. The more surface area of the inside filter (filter plates and substrate material covering the bottom of the tank), the greater will be the filtering capacity of the filter medium and, therefore, the greater the number of fish which the tank can safely support. A low flat tank has a greater filtering capacity than a high-sided tank of the same water capacity.

High-sided tanks were not tested or used in the MOP aquaria project to make a comparison of the filtering capacity.

<u>Undergravel Filter (Biological Filter Aid)</u>

This is a plastic base-plate covering most of the bottom of the tank to restrict substrate material from going underneath. Base-plates come in various sizes and configurations. All should have slits or spaces through which water can flow. Most plates come equipped with one-inch diameter airlift tubes of clear plastic. Each airlift tube is also equipped with end caps and smaller (1/8 inch diameter) inner airlift tubes to be used in conjunction with the air pumps.

Flat plates, 1/2 inch height, are equipped with one or two tube "portholes". These plates can be made more effective, in the transfer of water, by placing spacers (1/2 inch PVC pipes),*1 plastic tubing, plexiglass strips, or other similar material under the plate to provide more area. Make sure that these are evenly distributed under the plates so that the plates do not

*See Diagram: 18 Supplement page

crack under the weight of the substrate material. This method was used in the freshwater tanks and found to be quite adequate.

The other type of plates have a "wavy" surface at 1/2 to 1 inch high elevation, and are equipped with two to four lift-tube portholes. This increase of extra portholes in the filter gives flexibility to place the lift tubes in more desirable positions.*2 This proved to be the case with the S-55D tank in the MOP office. In May 1984, the replacement of the air pumps with outside filters was attempted. They not only increased the efficiency of the tank, but also increased the aesthetics of the tank. The filter plates within the tank were equiped with only two airlift tube portholes. The presence of the new outside power filters caused the hood covers to be tipped at an awkward angle. In June 1984, a breakdown of the tank was performed (see section on tank breakdown procedures) with the new filter plates installed, which had three-hole arrangements, thus, allowing better positioning of the outside power filter units and the hood covers could be placed in their proper position. Consequently, this increased the aesthetic appearance of the tank, and reduced the rate of evaporation of the water. The greater flexibility in airlift tube arrangements allowed by the additional filter plate portholes is recommended when purchasing filter plates.

Filter plates and airlift tubes can be constructed at home *3 using plastic "eggcrate" as a light diffuser for built-in fluorescent lights and PVC pipes. These pipes can be cut to fit the size of the tank. Time restraints prevented the attempt of homemade undergravel filter plates by MOP project members.

Filter Medium

The filter media should cover 1 1/2 to 2 inches in depth above the filter plate. The filter media houses organisms which break down and change the composition of potentially toxic products. The media must be the proper size to perform this function. The recommended size is 1/8 to 3/16 inch in diameter. If too small, anaerobic conditions may result; if too large, not enough area exists for good bacterial development.

Some animals, such as wrasses, bury themselves in the substrate material at night or when frightened. If the aquarium has such inhabitants, a finer substrate (smaller diameter) must be added to the tank. Larger materials will cause abrasions on the fish.

If such animals are placed in the tank, the filter media must be specifically arranged to accomodate them. Place the coarse material (1/8 to 3/16 inch in diameter) on the filter plates in a 1-inch thick layer. Place a patch of sand, about *4 1/3 the area of the filter plates and about 1-inch thick on top of the coarse layer. Fill in the rest of top layer with medium grain material. It is important that the sand not cover the entire top layer because this will cause anaerobic conditions in the bottom layer. This patch of sand will give the wrasses a place to "dive into", and yet the sand will be somewhat prevented from clogging the slits/slots in the filter plates.

*See Diagrams: 18 Supplement page

In time, some sand may filter through but this can be removed via a hose placed down the airlift tube and suctioned out.

Marine filter media: marine gravel, crushed coral, seashells, dolomite, and all materials with a calcium carbonate composition is recommended to automatically correct the pH in the water which will change over time.

For freshwater aquaria, stream or river rocks should be used as the filter media. The use of media intended for marine aquaria is not recommended because of the calcareous nature of the material. This will break down more rapidly in freshwater and may adversely affect the pH level in the tank.

Air Pumps, Tubing, and/or an External Outside Power Filter

Air Pumps

Air pumps were used the majority of the time and on the majority of the tanks managed by this project. Air pumps (Silent Giant, Apollo, and Whisper, etc.) are commonly used by most aquarists and are the types recommended by aquarium manuals. Air pumps have been successful and are standard in most aquarium systems and aquarium "how-to" books, but does have at least two problems: (1) they can be somewhat noisy; and (2) they can be very messy around saltwater tanks.

A prime complaint is the salt deposits and carbonate layers that form on the outside surfaces of the tank (i.e., lights, tank walls, covers, and any area adjacent to the tank). This is caused by the constant breaking of air bubbles on the surface of the water. Wiping away this encrustation is a constant and never-ending problem that requires daily maintenance.

Many aquarists, nevertheless, will choose to use the air pump method. (The MOP project is most familiar with this method.) Each air pump is rated as to the gallon capacity of circulation or its rate of air flow. The air pump capacity must be matched to the gallon capacity of the tank. The addition of more than one air pump is sometimes required to create the necessary air-flow rate for a particular tank.

The air pumps add air to the tank environment via tubing*5 attached to the pumps at one end, and to an airstone diffuser inside the airlift tubes at the other. This air is injected into the water as large numbers of small air bubbles. The air bubbles at the bottom of the airlift tubes are mixed with the water that is beneath the filter plate. As the air bubbles rise, they carry the water to the surface via the airlift tubes, with the displaced water being replaced with water flowing down through the filter medium in a constant circulation.

The efficiency of the air bubbles can be increased by decreasing the size of the bubbles and increases the numbers of bubbles. This can be done by the use of various types of airstones to diffuse the air bubbles. It can also be done by increasing the number of airlift tubes and directing the air from the air pump to a multiple number of tubes by the use of a gang-valve, designed in a series of arrangements (2-way, 3-way, 4-way, etc.). These gang-valves must be patiently adjusted to create an even flow from each tube giving off small air bubbles.

*See Diagrams: 18 Supplement page

Let the pumps run for about 30 minutes then check the flow through the valves again.

The greater the number of bubbles breaking on the surface of the water, the greater the oxygen and carbon dioxide exchange can take place. But, of course, this constant breaking of air bubbles can cause the "escape" of salt spray to cover everything outside of the tank.

Air pumps are fairly easy to clean and maintain. The rubber diaphragm should be changed about every two years. The two Silent Giant air pumps (#SG-1, #SG-2) which operate the S-85A were serviced in Sept. 1983. Two Apollo air pumps were purchased in Jan. 1984 and therefore are due for service two years hence.

Airlift Tubes

Airlift tubes, whether commercial or homemade, must be the proper length to efficiently perform their function. The tube should reach from the bottom of the tank to a point about 1/2 inch below the anticipated water surface This will allow the placement of an end cap or of a PVC elbow on top of the tube to direct the flow of air and water. With outside power filters, *6 the tube must be an inch above the anticipated water level. This will allow the power filter tube to be placed inside the airlift tube. (In either case the extra filter portholes should be capped to prevent the filter media from falling under the filter plates.)

Outside Power Filter

Another method of providing the needed aeration, and additionally, the filtering action of air circulation and water circulation through the filter medium, is with the use of an outside power filter. In May 84, two power filters, of the brand name Auto Flo, were added to the S-55D tank. In June 84, a Dynaflo 150 outside filter was added to the S-40H. Both tanks at that time, had their air pumps removed. Power filters (canister type) have been employed with the S-100F.

The outside power filter method has the advantage of: (1) quieter operation, (2) drastically reduce the salt encrustation problem that is encountered with air pumps, and (3) being used as a mechanical, chemical, and to a lesser degree, a biological filtration ~~method~~ aid.

Inside Corner Filters

There are corner filters which can be installed inside the *7 aquarium. These can be used as an adjunct, if the undergravel filter is not adequate, and also if there is a desire to provide additional aeration and filtration of the water to remove dissolved organic particles and/or medication. A combination of air pumps, outside filters, and corner filters can also be used to provide greater aeration.

*See Diagrams: Page 19 Supplement

Hood Cover and Lights

Covers

Tank covers should cover the entire surface of the tank top in order to: (1) reduce evaporation of water -- especially important in saltwater aquariums in maintaining the proper salinity of the seawater, (2) reduce splash and spray from air bubbles breaking at the surface from the use of air pumps, (3) eliminate the introduction of outside contaminants, such as dust, insects, objects, etc., and (4) prevent escape of some organisms.

Some fish, when frightened or startled, will jump out of the tank as has been the case in with some animals in the F-40B and the S-40H. Octopus and eels also have a tendency to escape and therefore a very secure cover is recommended. Although an octopus has not been kept by the project members, an eel has been a resident of the S-85A tank since Jan. 1984 and he has made no attempt to crawl out of the tank. Perhaps, he is too well fed to leave!

Hood covers can be made out of a variety of materials, such as glass or plexiglass, or commercial plastic covers. All have been used with varying degrees of success in the project. There are advantages and disadvantages to each type.

Glass: It is strong, inexpensive and has great clarity for viewing the fish from above the tank top. Its disadvantages is that its edges must be very carefully beveled and polished or aquarists will suffer sharp cuts on their hands. It can also break easily. It must be cut to fit the tank top and allow the fish to be fed.

Plexiglass: It does not break nor needs to have polished edges to prevent cuts. It will not break easily and it is lightweight. But it scratches easier than glass and very large pieces in thinner sheets, will bow when the weight of the light is placed on top (unless supports are placed underneath). It also must be cut to fit tank and cut to allow for feeding of fish.

Commercial plastic covers: They can be purchased ready fit for individual tanks and give a finished look. They have a hinged door for viewing and feeding. The only disadvantage is their cost -- the most expensive of the hood covers.

Lights

Lights simulate sunlight in natural wavelengths in a controlled manner, for growth of healthy tank algae and to enhance the beauty of the tank environment by enhancing the color of the fish and aiding in viewing the inhabitants.

There are various types of lights and light arrangements which can be used. The flourescent type lights are most commonly used as they produce little heat and come in the natural spectrum (daylight). Bulbs of 2 to 4 watts, with reflector, should be ample for most aquaria requirements. These are the types which were installed on all the MOP aquariums. They have been found to be adequate for their intended purposes, although they do not provide enough light for the growing of live corals or live plants over a long period of time. A more intense light (such as additional spot or flood lights) for just this purpose, has not been tested by this project. Most incandescent lights produce too much heat to be safely used.

A timer to control duration of light on each fixture is strongly recommended. Fish do best when the duration of light each day remains constant or changes very slowly. Fish should have 8 to 10 hours of darkness everyday. Plants (i.e., algae) need light in order to photosynthesize.

The covering of the tanks (and the turning off of the lights) during the evening hours when students were in the lounge has not always been successful, as it is impossible for the aquaria project members to be on the premises every evening at 7 or 8 o'clock to add the covers, and then to remove them in the mornings and turn on the tank lights. This has proved to be entirely impossible on Saturdays and Sundays when the fish received no auxilliary lighting during the day.

Timers have not been used due to a variety of reasons. (1) Hood lights that are activated by a "push in" type button, will not function with a timer. As these are the only type of lights that the MOP aquaria has, no timers were used. (2) Budget limitations, the purchase of timers and of hood lights of the type that "twist on", have prevented the use of such devices.

Timers would greatly enhance the quality of life for the aquaria inhabitants by controlling the daylight/nightlight hours of operation, but until a way can be found to encourage students using the lounge during the evening hours (when the room lights will be on), to place the provided covers for the tanks, the fish will not function at optimum level. Lights that come on suddenly, or off suddenly, or light that continues to function without the required 8 to 10 hours of darkness, will create an environment of stress for the fish. Stress is a predisposing factor in many diseases.

DECOR

Decorations, such as plants, coral heads, lava rock, pumice, tuff, large shells, and river or stream rocks (in freshwater aquaria), greatly enhance the beauty of the tanks and will provide a more natural environment for the tank inhabitants. This can assist in maintaining a less stressful environment for them and, therefore, a more successful aquarium.

In saltwater aquariums, make sure that nothing added has any metallic parts. Corals and shells (empty and devoid of any animals) can be cleaned easily with a high-powered water jet stream when removed from water, but BEFORE becoming dry. This will remove nearly all of the animal (coral polyp) of the coral and any debris or organisms that may be hiding within the crevices. Coral can also be soaked in a 50% chlorine bleach solution for 1/2 hour to a day until they are clean and as white as desired. Rinse VERY well, and place in the sun to dry for a week or more until no chlorine smell can be detected. This is the method which the project members used as access to a high-powered water jet was not available.

If the shells smell like dead animals, soak in pine oil or chlorine bleach solution, rinse well, and dry in the sun for a week or more until no odor can be detected. This cannot be emphasized too strongly; all traces of chlorine or pine oil must be gone from coral, lava, shells, etc., before placing in tank. If not thoroughly removed, a toxic agent will be added to the water which will completely disrupt the biological processes that are ideally occuring in the tank. The death of many fish have occurred this way, although none in the MOP aquaria due to the careful procedures in rinsing and sun drying of chlorine-cleaned decor.

Freshwater rocks, driftwood (from freshwater streams or rivers) can be rinsed and scrubbed very thoroughly with a stiff brush to clean. Additionally, they can be scrubbed with a solution of baking soda and then rinsed thoroughly. It is not recommended to dry the driftwood in the sun for it will "dry out" and float in the tank instead of lying along the bottom or propped at an angle on some large rocks among the plants. The rocks and driftwood in the freshwater tanks in the MOP lounge were all gathered in the Manoa Stream behind the University and after cleaning in the above recommended methods, were placed in the tanks. They have greatly enhanced the beauty of the aquaria and have given the inhabitants a more natural environment in which to live.

Water

Water for the freshwater tanks can be used directly from the water taps. Honolulu water is very clean and is not chlorinated, and therefore, does not need to sit for 24 hours or more to allow the elimination of chlorine gas to escape the water molecules.

Water for the saltwater tanks was normally obtained from the Waikiki Aquarium. They provide a public service of free filtered seawater, to all that ask, between the hours of 10 to 4, Monday through Friday. This water is filtered through coral and rock and drawn up a well for use at a faucet adjacent to the Aquarium. The method that the project used for obtaining water from the Waikiki Aquarium is explained in the section on Maintenance.

This water can be used immediately, and usually was, when making the monthly water changes or when setting up a new tank. But, the water can also be stored in a cool, dark place for up to three weeks and still used if aerated an hour or so before placing in the tank.

The purpose of using water at a later date than when initially taken is two-fold: (1) stored water is readily available in case of emergency or for later convenience in time restraints; and (2) stored water in dark containers and without an oxygen source, will usually have less possible pathogenic organisms to introduce into the tank. Water has been kept up to ten days and then safely used in the MOP aquaria. A longer period of time was not tested because of lack of storage space to keep the containers of water in the MSB (Marine Science Building).

Two other sources of seawater were used during this project. One source was from the large seawater storage tank located on the roof of the MSB. This tank had been recently filled with seawater and was offered for use by the Oceanography Department in the guise of Dr. Richard Young. Ten gallons of this water was used to start a quarantine tank for newly acquired fish. Within 24 hours, every fish in the quarantine tank had died. The chemistry of the water was tested and found to contain a nitrite level of over 15 ppm. This is certainly far in excess of the recommended level of 1 ppm or less.

Obviously the water in the roof storage had been contaminated by the construction materials of the tank and the lines leading to and from the tank. This water had not been used before, and therefore, no one knew or even suspected that this water would not be safe to use. A lesson was learned: do not ever use a new water source for the tanks until the water quality has been checked.

The tank on the roof would be the ideal solution to transporting water to the MOP aquaria, but until it is thoroughly cleaned and re-filled with "safe" seawater, it cannot be used. The MOP aquaria project members have volunteered to assist Dr. Young with this project and hopefully it can be accomplished soon.

Another source of water was obtained from Anuenue Fisheries. They have a large diameter pipe that lies along the ocean floor extending out some distance from their facility. It is pumped inland via a powerful pump. This water quality, chemically, was of the 1 ppm or less nitrate level, but because the pump that brings the water into the Fisheries facility is so powerful, it brings large quantities of dirt along with the water. To use this water a complex system of filtering would have to be employed to remove the brown mud lying at the bottom of the containment barrels and suspended in the water. This source was used only once.

<u>Other Useful Equipment</u>

<u>Hydrometer</u>

The hydrometer is a device for measuring the amount of salt solution in the water. It is sometimes referred to as specific gravity. There are two types of hydrometers that have been used in this project: (a) Floating hydrometer (may be portable or *8
remain in tank at all times): This is floated in the water and a reading is made on the stem. (Specific gravity should be read at the bottom of the curve of the meniscus, level with the surface of the water (see diagram)), and (b) Portable Hydrometer *9
box: This type of hydrometer is filled with water and a movable lever registrs the specific gravity on a scale engraved on the

*See Diagrams: Page 19 Supplement

face of the box-like plastic container. It does not measure temperature.

Pure freshwater should have a specific gravity of 1.000 because it should have no dissolved salts. Seawater should have a specific gravity of 1.024 with a range of 1.023 - 1.027. The range in salinity in seawater results from the evaporation of water in the aquaria with salts being left behind in the remaining water. See section on salinity.

Most hydrometers also contain a thermometer, but in Hawaii, without the strong temperature fluctuations, there is little need for a thermometer unless the tank is placed in an air-conditioned room (to which a tank heater with thermostat can be added), or near a very sunny west window which may raise the temperature to unsuitable levels. Temperature can range from between 65 to 85 degrees Fahrenheit for tropical fishes.

Both types of hydrometers were used and although the floating type can be left in the tank, it is more difficult to read especially by inexperienced people. The box type is easily read at a glance without possibility of error.

SETTING UP THE AQUARIUM

Cleaning and Checking for Leaks:

The new tank should be scrubbed with salt and/or baking soda solution to clean it of any residue. Used tanks can also be cleaned this way, and an additional solution of weak muriatic acid can be used to sterilize the tank from any organisms that may linger in the crevices of the tank seams. In either case, the tanks should be thoroughly rinsed with fresh water before using.

It is recommended that the tank be filled with water outside of the set-up area to check for leaks. If the tank has any leaks it can be easily repaired with silicone sealant made especially for aquarium use. Make sure that this type of sealant is used as other types of silicone sealants on the market contain materials toxic to the aquarium inhabitants.

The tank must be thoroughly dry and the area to be sealed must be cleaned with acetone to remove any oily residues which may affect the bonding qualities of the silicone. Apply a thin line of sealant and allow it to dry according to the directions on the container. After the tank has dried, add water again to the tank to verify that the leak had been fixed. This method was used on the saltwater 100-gallon tank (S-100F) to seal a small leak located on the upper right front side where the glass meets the frame; it was a sucessful bonding.

Caution should always be taken when moving any tank, especially one that is partially filled with water and/or substrate material. Shifting movements incurred in the transfer of the tank creates stress on the structural integrity of the tank seams. It is best to decide where the tank will be be permanently placed for display and then left alone. The S-55D (in the MOP office) had been moved to three different locations within the year that it was set up, and because of the great care care taken, it has produced only a small leak.

Location, Stand, and Air Pump

Avoid placing the tank in the direct sunlight. Direct sunlight coming into the tank creates rampant algae growth that may be difficult to control. The S-85A (in the MOP Lounge) has a great amount of sunlight entering through the end of the tank, producing a continuous heavy brown algae growth on the glass walls within a few days after removal. Also the direct sunlight will cause the temperature of the water to increase. The other consideration regarding the placement of the tank is the draft of the air conditioner, which chills the water. In general, avoid areas where there are likely to be great fluctuations in temperature as this causes stress to the fish.

Make sure there is easy access to the tank for feeding, cleaning, water changes and general maintenance of the tank once it is placed in position.

The support stand, whether of metal, wood, or concrete blocks, must be strong enough to support the weight of the filled tank. Remember, a gallon of seawater weighs about 8 1/2 pounds. Additional support for the bottom of the tank can be *10 made by placing a piece of styrofoam within the area of the underside of the tank. It should not be thicker than the space under the tank bottom or it will create stress (in an upward direction).

The air pump is normally placed in a position above the tank to prevent the accidental draining of water into the pump during a power failure. This is not always possible, and unless it can be stored out of sight it detracts from the appearance of the aquarium display. An alternate location for the pump can be below the tank stand. Merely place a loop in the air tubing *11 line above the top of the tank to prevent the accidental backflow of water into the pump (see diagram). This method proved satisfactory with the MOP aquaria project during two power outages (Hurricane Iwa and Black Friday).

Filter Plates

After thoroughly washing with clean water, install the undergravel filter plates and the airlift tubes in the aquarium. The plates should cover the bottom of the tank to the edges to prevent any small animals from crawling underneath and polluting the water if they should die there, as well as preventing any gravel, sand, and other substrate materials from sliding under.

Substrate Material

Wash the gravel, sand, or freshwater pebbles with tap water or use a weak solution of muriatic acid to remove any pathogenic organisms. In either case. substrate material should be rinsed thoroughly.

Distribute it over the filter plates to a depth of about 1 1/2 to 2 1/2 inches. This substrate material not only forms the basis for the biological filtration, but in addition functions to adjust the pH in saltwater aquariums. The substrate material must be the proper size to allow enough surface area to promote the development of nitrifying bacteria. Substrate should range in size from 1/8 to 3/16 inch diameter, unless you are adding a finer sand layer over the top portion of the substrate for wrasses and other organisms who need this shelter protection.

Filling the Tank

Place the largest pieces of the decor (coral heads, rocks, and other large decorations) on the substrate medium (gravel/pebbles). Add the water via a siphon hose, buckets, and/or pump. All fill the tank, but the pump will make the job more efficient and less messy. The water is poured <u>over</u> the decor in order not to disturb the even distribution of the substrate materials. When the tank is 3/4 full, add whatever

*See Diagrams: Page 19 Supplement

additional decorations desired for the tanks beauty and the enjoyment of the animals. Complete the filling of the tank; turn on the pump and allow to run for 24 hours so that the suspended sediment can settle and the water becomes clear.

Outside power filters can be used, but must not contain any activated carbon in the filter until the tank has been running for a few days. Carbon hinders the initial development of nitrifying bacteria. All of the MOP aquariums were started in this manner and have proven to be quite satisfactory.

Adding the Fish

At first, introduce only one or two very hardy types of fish and/or invertebrates to the aquarium. Members of the damsel family (e.g., Dascyllus albisella; white-spotted damsel), and hermit crabs or brittle sea stars are good animals to begin the tank.

New animals, which were from different water environments, must be gradually acclimatized to the aquarium's temperature, pH, salinity, etc. This can be easily accomplished by carefully transferring them and the water they arrived in to a clean rigid plastic container which can be floated in the aquarium.

After allowing sufficient time for the temperature to equilibrate, about 15 to 20 minutes, begin adding tank water to the container. Every 10 to 15 minutes, add a volume of tank water about equal to 1/5 the volume of the container. The container must be large enough to add this water and yet remain floating with the additional water added during this time. This will normally take one to two hours to safely acclimatize the fish. You may now add the fish to the tank by gently tipping the container and allowing the fish to swim out into their new home.

This may seem like a long and time-consuming process to perform each and every time new fish are placed into the tank, but the rewards will be the reduction of environmental stress that fish will have to endure, thereby ensuring healthier fish.

Fish, whether bought from the pet store, from a friend's tank or captured from the ocean, must be quarantined for a full three-week period prior to introducing them to the main display tank. This process of acclimatization must occur when introducing fish to the quarantine tank as well as the display tank.

THE FILTER SYSTEM

Filtration provides a powerful tool for processing waste products, that otherwise pollute the aquarium and kill the inhabitants, as well as keeping water crystal clear. Filter systems remove coarse and suspended detritus, which is the source of many of the undersirable substances in the water, and remove organic substances that cannot be further broken down by bacteria.

Many types of filter systems exist; all aid in either mechanical, biological or chemical filtration, and some also accomplish more than one filtration method. All three methods are important to water quality and healthy fish.

The undergravel filter is recommended for all tanks. This is where the biological filtration process occurs and is most important to the health of the tank, and was installed on all of the MOP aquariums.

There are two types of aids to the undergravel filter system. One is an air pump aiding the mechanical aspects of filtration. The other is a power filter aiding the mechanical, chemical, and to a lesser degree, biological filtration. Both types were used, with success, in the MOP Aquaria Project.

FILTRATION METHODS

Mechanical Filtration

The removal of coarse dirt particles suspended in the tank water -- excrement, uneaten food, bottom detritus, etc. -- takes place in the mechanical filter, which removes the coarse particles from the water passing through it in the fashion of a fine-meshed sieve. There are various filter mediums, some of which consists of dacron floss, nylon floss, polyurethane foam, and PolyFilter pads. These are layered in the outside filter unit or inside the corner-box unit.

This type of mechanical filter must be cleaned frequently by washing the filter floss or other material under the freshwater tap. It is recommended that this be done on a weekly basis, and changed entirely with the monthly water change operation. In this way, large amounts of detritus is removed from the aquarium before decomposition sets in.

The mechanical filter can also act as chemical filter with*12 the addition of activated carbon between the layers of filter floss material.

A new type of filter medium, PolyFilter (Bio Marine) has been used in the S-55D which has a longer life-span and is more efficient in removing harmful material from the water.

*See Diagrams: Page 19 Supplement

Inside corner-units were used primarily in the freshwater tanks (F-15C and F-40B) since the under-substrate filter plates for those tanks were not adequate for proper water circulation. Outside filter units were installed on the S-40H and S-55D (May 1984), and the S-100F (July 1984), which should prove to be quite successful in maintaining water clarity.

Mechanical filters, whether inside or outside, can also function as a biological filter if it operates long enough between cleanings (or is rinsed in seawater for saltwater aquariums). This prevents the killing of the nitrifying bacteria in the floss material. This biological filter medium can be very important to conserve especially during a period when a tank is to undergo radical tank break-down and cleaning. This method was used in the break-down of the S-55D during its relocation from the MSB Lobby to the MOP offfice in November 1983, and again during the radical cleaning and equipment modification done June 1984.

The filter material was kept immersed in seawater to prevent the dying-off of the nitrifying bacteria. The filter medium, after the cleaning operation, was then re-installed in the filter box without rinsing. This gives the tank a "seed" of "good" bacteria to re-establish itself to the proper bacterial levels to handle waste materials from the animals in the tank.

Chemical Filtration

Chemical filtration removes dissolved compounds and elements from the aquarium water. There are four basic chemical filtration methods commonly used. These are: activated carbon, ion exchange resin, protein skimming (airstripping) and oxidation through ozonation.

Activated carbon removes dissolved compounds and elements from the aquarium water, because each carbon grain contains microscopic pores. These pores absorb dissolved compounds of various organic and inorganic substances from the water and trap them so they no longer present a problem. When all the pores are filled, the carbon is deactivated and functions only as a biological filter. This takes quite some time, depending on the filtering load.

Because carbon absorbs dissolved compounds, it must be kept in an airtight container when not in actual use or it will be useless as a chemical filter when placed in the filter box. Deactivated carbon should not be recycled. During the monthly water changes it is best to replace the carbon in the filter.

Caution must be taken in using activated carbon on invertebrate tanks because invertebrates seem to be more dependent on trace elements than do vertebrates. Carbon can be used with greater frequency on vertebrate tanks, especially older carbon (which is better than new carbon because it retains the capacity to remove large organic molecules after its affinity for simpler compounds has diminished).

Some authorities believe that aquariums should be given frequent rests from carbon filtration, especially immediately after water changes. None of the MOP aquaria have had carbon filtration for long enough periods of time to determine whether long-term use adversely affects the animals. But, in a home-control tank, activated carbon has been used on a daily basis for a period of eight years, and all animals are very healthy.

Some of the things that activated carbon will remove, to some extent, are: oxygen and carbon dioxide (but not enough to affect a well-aerated aquarium), copper, ozone, chlorine, many antibiotics, some dissolved proteins and carbohydrates, iodine, mercury, vanadium, chromium, cobalt, iron, molybdenum, methylene blue, malachite green, sulfa drugs and organic dyes.

Most compounds are not completely removed by activated carbon, but are reduced in concentration to variable extents, depending on the filled pores-spaces of the carbon. Some compounds are easily removed (e.g., organic dyes), while others (e.g., mercury) are more difficult or impossible for carbon to effectively remove from the water.

Do not use activated carbon on the quarantine tank. It will remove the medication that was placed in the water to treat the animal. If the main display tank has been treated, this process can be used to remove the medication prior to the addition of invertebrates. Most invertebrates are intolerant of medication.

Ion exchange, protein skimming and oxidation through ozonation have not been tested by this project because of their complexity, and in some ways, expense, this project was not prepared to accept.

Biological Filtration

The other types of filtration are important and helpful, but biological filtration is of upmost importance to the aquarium and its healthy function.

There are basic types of contaminants in aquarium water -- suspended physical particles and dissolved chemical compounds. Physical particles vary in size; the dissolved chemical compounds may originate inside or outside the tank.

Dissolved chemical contaminants normally are created from the metabolic waste materials of the inhabitants and from bacterial activity of the organic waste matter produced in the tank. These dissolved chemical compounds include ammonia, nitrite, nitrate, urea, proteins, amines, fatty acid, phenols, and dyes. Outside chemical compounds may be: insect spray, paint fumes, soap and perfume on the hands of the careless aquarist.

Biological filtration is the transformation of these toxic waste substance, primarily ammonia, into relatively non-toxic substances through the activity of living organisms, primarily nitrifying bacteria. Waste products, (undigested food, intestinal bacteria, carbon dioxide, and nitrogen wastes from utilization of protein and normal breakdown of body cells) are produced by every tank inhabitant and must be eliminated by that inhabitant.

The biological filter does not REMOVE these waste substances from the water; it only CHANGES them to a form less harmful to tank inhabitants during the nitrogen cycle. Because it only reduces these waste substance's toxicity, the need for periodic water changes is mandatory.

The carbon dioxide content of the aquarium remains stable despite the constant production by the animals and utilization by algae. Some of the CO_2 passes back and forth with the atmosphere via exchange at the surface with the aid of aeration at the surface of the tank water. The remainder is either taken up by algae or enters in an ion equilibrium which affects the pH of the aquarium.

The solid wastes of fish and invertebrates, uneaten food, dead animals (undiscovered by the aquarist) all affect the pH -- acidity/alkalinity balance -- of the water. These wastes are attacked by aerobic bacteria during the nitrogen cycle, decaying the dead matter and producing ammonia from the decomposed protein (i.e., ammonification). In high concentrations, ammonia is toxic.

The major source of ammonia in a well-run aquarium is from the nitrogen wastes of the animals. They must rid themselves of the toxic material in their blood, which is formed from the break-down of proteins. Fish rid themselves of waste nitrogen primarily through their gills into the surrounding water.

These two sources of toxic soluble ammonia (derived from the activity of decay bacteria and animal excretion), must be compensated for or the water environment will become unhealthy for the tank inhabitants. This is where the biological filter earns its worth.

Nitrifying aerobic bacteria (requiring oxygen) have the capacity to oxidize ammonia. The substrate material provides a surface for the bacteria to colonize. The bacteria genera are Nitrosomonas and Nitrobacter. Nitrosomonas oxidizes ammonia to nitrite, and then Nitrobacter changes nitrite to nitrate.

The intermediate product, nitrite (NH_2), is also toxic but less so than ammonia. The end product, nitrate (NH_3), is relatively non-toxic and is not of great concern to the aquarist. However, if anaerobic (not requiring oxygen) conditions exist where pockets of low oxygen develop in the tank, bacterial reduction of nitrate can produce toxic compounds. These anaerobic conditions can occur if large areas of the substrate material is covered with large coral heads, large rocks, and other large decorations which prevent the bacteria from receiving adequate amounts of oxygen. This condition can be avoided if air spaces are provided under the larger pieces of decor with the use of smaller rocks beneath the larger or using large rocks with large, uneven indentions of their bottom surfaces.

NITROGEN CYCLE

Ammonia occurs in two states, depending on pH: the unionized state (NH_3) and the ionized state (NH_3+4). The unionized state is more toxic than the unionized state because it invades body tissues more readily, but fortunately, almost all free ammonia is in the ionized state at the normal pH of seawater. As the pH increases, non-toxic forms of ammonia rapidly decrease, and the toxic forms rapidly increase.

At higher pH values, there are fewer hydrogen ions. Consequently, more of the ammonia exists in the unionized form. This characteristic accounts for the significant difference between establishing freshwater and marine aquariums. In the pH range normally encountered in freshwater systems (near 7 = neutral), most of the ammonia is in the ionized form. At pH values found in saltwater systems (8.0-8.4 = slightly alkaline, or basic), a significant portion of the ammonia exists in the unionized, toxic form. This is why new freshwater systems may be stocked quickly with sizeable populations, whereas new marine systems must be stocked quite modestly at first, and the population increased gradually. Thereby, time is given to allow biological action to convert the ammonia to a less toxic molecule, the nitrite ion. Levels of ammonia and nitrite should always be very near zero in the aged and balanced marine aquarium.

The Nitrosonomas bacteria are the first to populate the filter and rapidly begin oxidizing ammonia to nitrite. Nitrobacter is inhibited by the presence of ammonia and does not begin rapid population growth until ammonia levels begin to fall. It can then begin converting nitrite to the less toxic compound, nitrate.

Obviously, these bacteria cannot grow unless their nutrients, ammonia and nitrite, are present in the tank. They can be provided naturally by introducing some hardy fish and/or invertebrates, or artificially by adding a solution of inorganic ammonia (e.g., Nitro Quik). Another method to begin the bacterial growth, is to "seed" the new tank with some bacteria (scooped up in the substrate material from another healthy and balanced aquarium) in addition to adding some hardy animals. This method and the natural method of beginning with hardy animals have both have been applied with success in the MOP aquariums. The advantage of using "seed" is that, obviously, the tank can obtain a larger population of bacteria far more quickly than merely beginning with the hardy animals; the wastes from the animals must accumulate to the point that bacterial action can begin. The disadvantage of using "seed", is that this may introduce some undesirable organisms into the new tank from the old one. It is recommended that if this is the choice, take the longer way and begin the tank with the hardy animals.

The purchase of nitrifying bacteria in freeze-dried form (e.g., Nitro Quik) that can be added to the aquarium when it is first set up, can provide the right kind of bacteria and can decrease the time when bacterial populations begin the nitrite to nitrate process. The addition of some hardy animals, along with this bacteria, accelerates the nitrogen cycle. This method should shorten the conditioning time by a week to ten days, depending on the amount of freeze-dried bacteria initially added to the tank.

Sufficient populations of bacteria needed for the conversion process must grow in a relatively sterile, new filter bed. It will take some time for such numbers to develop if only a few bacteria are present at the start. Therefore, starting with a larger bacterial populations accelerates the process of growth to proceed more rapidly in the secondary phases than in the primary phases. The development of Nitrosomonas, during the primary phase, converts ammonia to nitrite. The development of Nitrobacter, the secondary phase, now converts nitrite to nitrate. This is why ammonia and nitrite levels drop so rapidly to less than one or two ppm, usually within a day or two, even though they were building to high levels over a period of several weeks. Obviously, starting out with a bacteria population of some size, the time required to establish the necessary nitrifying potential will be shortened.

After the populations of Nitrosomonas and Nitrobacter are well established, oxidation of ammonia and nitrite occurs as these compounds are formed. Thus, they never accumulate in the system and only the end product, nitrate, can build to high levels. Nitrate can be removed by dilution through partial water changes, or since it is a basic plant nutrient, algae growth in sufficient number and quantity can prevent high concentrations. Nevertheless, periodic water changes are recommended and was the method most relied upon for the elimination of nitrate buildup in the MOP aquaria.

TESTING DURING THE NITROGEN CYCLE

Chemical testing for nitrite is important during the conditioning period of a new tank because it keeps the aquarist informed on the progress of the tank, when the process is complete, and when no more nitrite remains in the tank. Nitrite*13 levels appear in the tank around the tenth day and gradually rises to a peak near the 15th to 30th day. The first few days will show no indication of nitrite because only ammonia will be present, but eventually the test will indicate varying degrees of nitrite. The nitrite cycle is much the same as the ammonia cycle except that it usually takes longer. Nitrite usually becomes measurable on the 7th to 10th day after fish are introduced.

See Diagrams: Page 20 Supplement

Keeping accurate records of daily water tests for nitrite is important. In most cases, nitrite levels will rise, peak, and then fall to zero somewhere between the 15th and 30th day. After a few weeks there will be no indication of nitrite because of its immediate conversion to nitrate. The conditioning sequence is now complete and the biological filter is fully functional. Let the aquarium stay as it is for another two to five days before adding more fish.

After this initial period, additional specimens may be added. It is always wise to increase the population gradually to allow the biological filter to adjust to the increased load. Adding another animal increases the amount of waste products in the aquarium and the biological filter needs time to adjust to the greater amount of ammonia. As a general rule, add only one or two animals at a time and wait seven to ten days before adding more. When the new fish are added, nitrifying bacteria begins to reproduce at a greater rate because there is more food available.

By allowing this initial period the tank inhabitants will never be exposed to unhealthy levels of ammonia or nitrite. When adding new specimens, always monitor the nitrite level. This rule applies to new tanks as well as older established aquariums. It is possible to break this rule and get away with it, but adhering to it greatly increases the chances of success.

The validity of this rule was, unfortunately, confirmed by problems encountered with a newly established tank (S-85A) and with an older established tank (S-55D) in the MOP project. The S-85A was established as a new tank on July 30, 1983 and was initially started with "seed" from a healthy established aquarium and with the requisite hardy animals, in this case, two Dascyllus albissea (white-spotted damsel) and one Ophiocoma pica (brittle sea star). Within nine days, thirteen additional animals (vertebrates and invertebrates) had been placed in the tank (without MOP project approval!) and then five days later, another nine animals "appeared" in the tank, again without project approval. Even though some of these animals were moved to another aquarium, it was apparently not enough to assist the already overworked biological filter. Within a few days after the addition of animals and with a 25% water change made, the more delicate animals (e.g., Chaetodon lunula (Racoon butterfly), C. auriga (Threadfin butterfly), Forcipiger flavissimus (Long-nose butterfly), and the Zebrasoma flavescens (Yellow Tang) began to die, nearly one per day until only the most hardy of fish survived (e.g., Chromileptis altivelis (polka-dot grouper). This great fish eventually succumbed, even though he had been removed and placed in a quarantine/hospital tank for treatment of a persistent fungus infection.

The older established tank, S-55D, had on two different occasions, a large number of fish placed in the tank without the recommended gradual introduction period. The tank, established nearly five months, contained six fish and five invertebrates. Ten more fish were donated to the tank and within two weeks began to die on a weekly basis. The Gobbiidae sp., being very hardy, were the only survivors. Again, in January 1984, with the tank having been established for nine months, six more fish were placed in the aquarium. These were all Chaetodons and within two weeks all had died.

During the time the tanks were set up and the animals were being added, nitrite readings were being taken. Usually these readings read within the acceptable levels (less than 5 ppm), and because of this observation it was assumed that the water quality was normal and no problems existed. Now, only with hindsight and a more thorough understanding of the functioning of the biological filter and its limitations, that the problem was a rapid rise of ammonia in the aquarium resulting from the increased amounts of waste products of the many animals. The nitrifying bacteria in the filter could not keep up with this increased load and the stress of ammonia concentration in the water resulted in the deaths of the animals.

Another possibility is that nitrate will undergo reduction to ammonia. Ammonia accumulates fairly readily when there is a sudden rise in the amount of organic matter being decomposed, and this combined with the ammonia the aquarium animals normally excrete may overwhelm the system. When ammonia accumulates, further oxidation of nitrite to nitrate is seriously impeded.

Testing for ammonia was never done. It was usually not necessary because the presence of nitrite (verified by the nitrite test kit) indicated whether ammonia was present and that the Nitrosomona had converted ammonia to nitrite. In addition, studies conducted (FAMA, December 1979) indicated that test kits for hobbyists for ammonia were generally unreliable and that "research-quality" test kits were generally too expensive. The MOP project, generally under-funded, did not purchase any ammonia test kits and therefore, the validity of their use has not been made.

Even without the ammonia test kit, the problem could have been eliminated if STRICT control on the number of fish added (one or two) to the tanks and the proper conditioning period (seven to ten days) before more fish were added, had been maintained. It is strongly recommended that this rule not be violated again or similar results may occur.

MAINTENANCE

Aquariums require regular care and maintenance. This is to be done on a daily basis, usually during the time when feeding the animals; monthly, done in conjunction with the water changes; and yearly, when the filter bed and coral must be cleaned.

Equipment used in connection with maintaining and cleaning the aquariums (small nets, siphon tubes, sponges, containers) must be made of non-corrosive materials and never used for anything other than aquarium purposes. These items should never be washed with soap but should be thoroughly rinsed with freshwater after each use.

During the cleaning operations, unplug all electrical equipment: air pumps, power filters, and lights. Spilling water on connections, plugs, or sockets may blow a fuse or worse, shock the aquarist or the fish.

Another axiom is to limit maintenance operations in the aquarium. The less interference with the aquarium environment (provided it is healthy!), the better. Unnecessary cleaning every week may prevent the establishment of stable conditions. Above all, avoid constant tinkering with the aquarium (to improve a small detail here and there). Fish need to feel safe in their own familiar, quiet nook. If the layout of the aquarium changes constantly they never settle down. A newly stocked aquarium or new specimens, in particular, should be left alone as much as possible.

DAILY MAINTENANCE

Generally, restrict maintenance to the observance of the animals: eating/ not eating, signs of disease and deterioration, whether they hide in corners, are fighting, or are listless. The observance of air pumps, power filters, working lights, and closed hood covers should also be made. In addition, water clarity and smell should be noted. If there is a slight cloudiness of the water, or if the water gives off an odor or persistent heavy foam there is probably a dead fish lying hidden behind the coral/rocks or a large quantity of uneatened food. The uneatened food and the water must be siphoned out through a fine-mesh net or removed with the use of a wad of filter floss. The filtered water can then be returned to the tank. To avoid having a dead fish lie unobserved behind rocks/corals check the entire population everyday; this is not always easy to do, as certain species may hide for hours. Wrasses and certain other species sometimes hide in the sand for over a week when first introduced to the aquarium. If, on the other hand, an individual of an active species does not show up for a relatively long time there is reason to assume something unfortunate may have occurred. Lift the corals and rocks gently as to not frighten the other fish and look for the missing, possibly dead, animal.

An additional cause of excess dissolved organics in the water may be the reduced capacity of the biological filter-bed to handle the waste products. Mechanical filtering quality of the filter medium may be reduced by excess detritus. This can be corrected during a cleaning of the filter-bed.

WEEKLY MAINTENANCE

Of utmost importance are the weekly checks on water quality (pH, specific gravity, nitrite levels). Attention to maintaining water quality will insure that the fish are never subjected to this environmental stress. See the section on Water Quality for further explanations.

MONTHLY MAINTENANCE

Approximately 25% of the aquarium water should be replaced with fresh saltwater every month for marine aquariums, and with less frequency, freshwater aquariums should have 25% of the water replaced with fresh tap water. A partial water change provides a number of important benefits: pH is stabilized, accumulated dissolved metabolites (nitrate and organic compounds) are diluted. Additionally, this will safeguard against depletion of trace elements (very important to invertebrates), and does much to prevent stress and disease caused by environmental factors.

A weekly 10% water change is optimal, but since water was not readily available at the Marine Science Building site, a compromise was made with a monthly 25% water change with water from the Waikiki Aquarium.

About every three months, a greater water change was made (50% or more), but this is not recommended on a monthly basis because it creates stress on the fish because of the rapid changes in water quality factors (e.g., temperature and pH).

As water is removed from the aquarium, excess detritus may also be removed via the siphon hose. Stir the substrate material with fingers. Since detritus is much lighter than the gravel/pebbles, it will float up into the water and settle on the surface of the filter-bed. Here it can be siphoned out easily along with the remaining 25% of water. Only a 1/4 section of the filter-bed should be cleaned in this manner during the water change. This will reduce the upset in the biological activity of the nitrifying bacteria in the filter medium. Siphoned marine substrate material should be rinsed in <u>saltwater</u>, not freshwater, to prevent the death of many nitrifying bacteria in the filter-bed. Another procedure is to remove the tank water close to the bottom, from under the filter plates, by inserting a flexible siphon hose into the airlift tube and siphoning the water out. The siphon tubes should not be too narrow. The tube should fit as securely as possible in the uplift tube in order to obtain maximum suction action. This can be performed every three months or so.

The inside panes of glass can be easily cleaned of heavy algae growth. Algae should be removed from the front and side panels to aid in viewing the animals. The panes not normally looked through should not be cleaned on a monthly basis. This gives the aquarium a more natural look and preserves valuable algae. White Nylon sponges or pads are very effective for cleaning. Care must be taken not to scratch the glass with other more abrasive types of cleaning pads. Additionally, scratching of the glass may occur if shell grit or coral pieces are rubbed against the pane. To prevent this, when cleaning the inside glass, be careful that particles are not picked up by the cleaning sponge/pad.

Salt deposits around the light housing should be cleaned off to help optimize light intensity and prevent possible electrical shorts. Strip lights, which have a cover panel, can easily be disassembled for this purpose. Cleaning the underside of the light-cover glass is also important, especially if algae grows well there. The tank top should be wiped clean of salt deposits and the air stones checked. If the air stone output is failing it is usually because the pores have become clogged or the material is disintegrating.

Filter canisters, with filter floss and/or activated carbon, needs to be checked for proper operation. If the floss material appears very dirty replace it during the monthly maintenance, otherwise it may be replaced less frequently. A new type of synthetic filter floss is being used in the S-55D and will be used in the S-100F called the PolyFilter. To check whether it is still functioning optimally, observe its color change; it will progress from an off-white to a brown color after prolonged exposure to contaminants in the aquarium. Cut the PolyFilter in half, crosswise, when it is brown-colored. If the cross-sections also are brown, it is time to replace with a new one.

Every two or three months, check the functioning of the air pump and power filter. The pump body and the impeller (of power filters) becomes coated with algae and "muck" which can drastically reduce the output performance of the pump. It is recommended that pumps be removed and cleaned to maintain their maximum output. If the flow from an air pump is reduced, even with the replacement of the air stones, check the air flow output. If it is low, the diaphragm probably has split and a replacement is necessary. This diaphragm split will increase over a period of a few days and the output from the pump will become zero.

Every three months, during the greater water change, clean the filter stems and plastic tubing. If the coral or rocks are very dirty they should be cleaned at this time also. It is recommended that only one or two be removed and cleaned on periodic days to reduce the environmental stress.

An important procedure for maintaining healthy aquariums is to include marine animals that aid in removing uneatened food. Having a "cleaning crew" at work all the time reduces labor for the aquarist and prevents trouble. Recommended animals are: hermit crabs, brittle stars, and coral-banded shrimps. Hermit crabs, particularly large ones, can gradually turn a filter-bed over completely and consume uneatened food, algae, and some detritus.

YEARLY MAINTENANCE

It is recommended that an aquarium be "broken down" to completely clean the tank, filter plates, airlift tubes and substrate material. This is a major undertaking and requires a large portion of time and effort, but the rewards will be a healthier environment for the aquarium animals, _if_ this procedure is performed with care.

Gravel or substrate in saltwater aquariums serves two major purposes: (1) aids in buffering the water to a suitable alkaline pH and (2) provides the large surface area required to house the beneficial nitrifying bacteria. Over periods of time, which are not well-defined (variables may be numbers of animals and/or plants in aquaria, as well as water temperature), the substrate becomes less efficient as a buffering agent. There are at least two likely reasons for this. First, the gravel surfaces becomes coated with dissolved or suspended organics. Second, it has been postulated that phosphate may replace carbonate at the gravel-grain surface. In either case, some non-buffering agent essentially coats the carbonate surfaces and prevents interaction between the water and the carbonate. Regardless of the mechanism of the buffer deactivation, it is recommended that periodic (perhaps every two years) replacement of gravel be performed or that the gravel be washed to remove the dissolved organics on the coated substrate material. This is not the easiest task but is not as difficult as it might first appear. New gravel can be purchased and rinsed well in preparation. A part of the old gravel can be removed, down to the filter plate, and with the new gravel can then be installed.

When substrate replacement becomes necessary, replacement*14 of only 1/3 of the gravel is recommended (at three-month intervals), since the new gravel requires time to acquire a bacterial population and the biological filter is only 2/3 as efficient during the interim. Monitoring ammonia and nitrite concentrations can indicate any serious loss of nitrifying ability. Any consideration of adding new fish at this time should be put off for a few weeks to give the biological filter time to catch up in capacity.

The procedures for performing this "break down" are as follows:

1. Remove at least 1/2 of the water by siphoning it into a container,

*See Diagrams: Page 20 Supplement

2. Remove the rocks and corals to these containers where they may be scrubbed clean of excess algae or detritus. After taking the corals from the tank, check them very carefully because frightened species often hide there, or, as in the case of many invertebrates which reside there, will stay put even when the coral is removed from the water. If this should happen place this piece of coral in a container of old tank water, removing the coral when the fish has left it. Set aside after cleaning.

Removing all the corals from the tank before removing the animals will make capture of them that much easier and thereby reduce excess stress to them. The risk of harming the fish would be very great with decor in the tank as they when frightened, will dash into hiding places as quickly as possible. Another reason the water level in the tank must be lowered is that many species attempt to jump out of the water when chased (e.g., lobsters).

3. Remove the animals to another container with aeration which has 1/2 of the "old" tank water and 1/2 of the "new" tank water. This gives the animals time to adjust (acclimitize) to the different water conditions they will encounter when returned to their tank.

4. Scrape algae from the aquarium with white nylon pads or sponges.

5. Remove the gravel via the siphoning of the remaining water and rinsing it clean of detritus, in saltwater to be discarded. This avoids destroying all the bacteria in the substrate material. This, thus, preserves at least some of the algae, microfauna and flora so badly needed in the newly cleaned aquarium.

6. The filter medium in the power filter should be immersed in old tank water. This is another source of biological bacteria which is valuable to preserve.

7. The airlift tubes may be cleaned at this time by removing them from the filter plates and using a long, flexible brush to clean the algae coating the interior of the tubes.

8. The filter plates may also be removed and the brown "muddy" water under the plates be siphoned or "mopped out" of the aquarium.

9. The filter plates and substrate, coral/rocks, may be returned to the tank and then the new water added to 1/2 the tank depth. Allow this water to equalize to the same temperature as the container in which the animals have been kept, and to allow some of the suspended material to settle. Replace coral and rocks.

10. Add the animals to the tank and allow them to settle in for a few minutes.

11. Add the rest of the new water slowly, over a period of a few hours, to give the fish time to adjust to the changes in water variables (e.g., pH, specific gravity, and temperature).

The tank itself, is another area of long-term maintenance. Seams should, obviously, be inspected for signs of sealant attrition. If there are small leaks the tank will have to be broken down for thorough cleaning and resealing.

Tank lighting is an area often overlooked. Replacement of the fluorescent lights is ideally done every year but may be replaced every two years. Replacement schedules vary considerably depending upon tank depth and average daily use, to name a few variables. A high light-intensity is desired because it is intimately related to good growths of algae. The contrast in brightness is immediately apparent in the increased brilliance of fish colors.